

MULTI-POINT POLYMER ENCAPSULATED MICRO-THERMOCOUPLE

Technical Field

This patent application relates to thermocouple devices, and in particular, to
5 a thermocouple device produced by encapsulating a thermocouple junction with a
heat-shrinkable polymer coating.

Related Applications and Claims of Priority

This application is a continuation-in-part of U.S. Patent Serial No.
10 10/391,531, filed on March 17, 2003, which claims the benefit as provided under
35 U.S.C. § 119(e) to U.S. Provisional Application No. 60/366,435 filed March 21,
2002, which is hereby incorporated by reference in its entirety. The application also
claims benefit as provided under 35 U.S.C. § 119(e) to U.S. Provisional Application
No. 60/455,617, filed on March 17, 2003, which is hereby incorporated by reference
15 in its entirety.

Background

A thermocouple is a bimetal junction that provides a voltage proportional to
temperature. Temperature probes are often formed using thermocouples. Many
20 applications requiring temperature probes require extremely small size.

One application for extremely small temperature probes is in the medical
device industry; especially for use in catheters. For example, ablation catheters are
used in non-invasive treatment of heart abnormalities. The ablation catheter is able
to identify abnormal tissue growth and uses heat to remove the tissue causing the
25 additional conduction paths. Thermal feedback is required when removing the
tissue to prevent blood clotting or blood boiling during the procedure. In using a
temperature probe to provide this feedback, the probe must be small enough to get
as near an ablation electrode as possible. Also, when used in catheters, it is
desirable that a temperature probe not rupture a catheter sleeve by tearing or
30 abrasion. Further, a probe should be electrically insulated to allow *in vivo*
operation.

It is apparent that uses for extremely small temperature probes beyond the medical field are possible. An extremely small probe would be useful in any field where a measurement of a localized temperature variation is desired, such as for example, the field of electronics.

5 What is needed is an insulated thermocouple device of extremely small size.

Summary

This document discusses an insulated thermocouple device of extremely small size. The thermocouple is produced by removing insulation from distal ends
10 of two thermocouple conductors and then forming a thermocouple junction at the distal ends of the two thermocouple conductors. A tube of heat shrinkable polymer material is placed over the thermocouple junction. The entire thermocouple junction is then sealed by heating and melting the polymer material.

The resulting thermocouple and seal fall within a reproducible confined
15 shape, where the height of the confined shape falls within a range of about 0.003 to 0.010 inches and the width of the confined shape falls within a range of about 0.005 to 0.0110 inches.

This summary is intended to provide an overview of the subject matter of the present application. It is not intended to provide an exclusive or exhaustive
20 explanation of the invention. The detailed description is included to provide further information about the subject matter of the preset patent application.

Brief Description of the Drawings

In the drawings like numerals refer to like components throughout the
25 several views.

Figure 1 is a drawing of one embodiment of the micro-thermocouple.

Figure 2 is a flowchart showing one method for forming the micro-thermocouple.

Figure 3 is a drawing showing fused embodiments of the micro-
30 thermocouple.

Figure 4 is a drawing of an embodiment of the micro-thermocouple that comprises two thermocouple junctions.

Figure 5 is a drawing of an embodiment of the micro-thermocouple that comprises two thermocouple junctions at different locations along the length of the
5 device.

Detailed Description

In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and specific embodiments in which the
10 invention may be practiced are shown by way of illustration. It is to be understood that other embodiments may be used and structural changes may be made without departing from the scope of the present invention.

As stated previously, the present application is concerned with materials and techniques used to create a sealed thermocouple of extremely small size. Figure 1
15 shows one embodiment of a micro-thermocouple 100. The thermocouple junction 130 is formed from joining conductors 120, 122 of dissimilar metals. The metals comprise any of the standard metal combinations defined by the American Society of Testing and Materials (A.S.T.M.) for thermocouples. The size of the thermocouple conductors generally fall with a range of about 30awg (0.010 inch
20 diameter) to about 50awg (0.0009 inch diameter). In one embodiment conductors 120, 122 are joined to form a thermocouple junction 130 by soldering using lead-free solder 135. In another embodiment, conductors 120, 122 are welded and 135 represents a welded bead or seam. Beyond the thermocouple junction 130, the conductors 120, 122 are electrically insulated with commonly used insulating
25 material 140 such as nylon, polyurethane, or polyimide. A heat shrinkable polymer material is then used to form an electrically insulating seal 150 over the micro-thermocouple 100. To create the seal 150, a tube is slid over the thermocouple junction. In one embodiment, the tube is slid over the thermocouple junction and the seal 150 is then formed by heating the tube of polymer material to the point of
30 melting onto and over the thermocouple joint 130 and onto the insulation 140. Melting the polymer material onto the thermocouple conductor insulation 140

provides a seal around the insulation 140. The melting also forms a domed shape 155 on the end of micro-thermocouple 100. This domed end 155 is advantageous if the thermocouple is used in a catheter as it results in the micro-thermocouple 100 being resistant to abrading or tearing a catheter sleeve. In another embodiment, the tube of heat shrinkable polymer material is first sealed on one end by melting the end and forming the domed end before the tube is slid over the thermocouple junction. After the tube is slid over the thermocouple junction 130, further heating and melting provides the insulating seal 150. Other embodiments involve sealing the end while it is placed over the thermocouple junction 130.

10 The length (l) 160 of the resultant seal 150 is within the range of about 0.05 inches to 0.5 inches. The overall length (L) 165 of the micro-thermocouple 100 is within the range of about 20 inches to 78 inches. One embodiment of the micro-thermocouple 100 uses polyethylene terephthalate (PET) as the polymer material. Another embodiment uses fluorinated ethylene propylene (FEP). The seal 150 is
15 moisture resistant and electrically insulating. The insulation resistance of the seal is greater than 100 Mega-ohms when measured at 50Volts(DC).

 Figure 1 also shows a cross section 110 of micro-thermocouple 100. The width (w) 170 of the micro-thermocouple 100 falls within a range from about 0.005 inches to 0.011 inches. The height (h) 175 of the micro-thermocouple 100 falls
20 within a range of about 0.003 inches to 0.01 inches. Thus, it can be seen that the micro-thermocouple can be formed within a reproducible confined shape having a height 175 less than about 0.01 inches and a width 170 less than about 0.011 inches. The final dimensions of the confined shape is determined in part by the gauge of the thermocouple conductors used. Providing the insulation by the technique described
25 herein adds about 0.0005 inches to the width and height dimensions of a formed thermocouple junction.

 Figure 2 shows a flowchart of one embodiment of a method 200 of forming micro-thermocouple 100. At 210, insulation 140 is removed from a distal end of thermocouple conductors 120, 122. At 220, a thermocouple junction 130 is formed
30 at the distal end of the conductors 120, 122. At 230, the tube of polymer material is

slid over the thermocouple junction 130. At 240, a seal 150 is formed over the thermocouple junction 130 by heating and melting the polymer material.

Figure 3 shows fused embodiments of the micro-thermocouple 100. A fused thermocouple prevents the possibility of recycling or reusing the thermocouple if the micro-thermocouple 100 is used in a medical device. In one embodiment a fuse 390 is placed in a thermocouple conductor 120 between a proximal end of the conductor 120 and the thermocouple joint 130. Exceeding the rating of the fuse breaks the electrical connection between the proximal end of conductor 120 and the thermocouple joint. In another embodiment, a fuse 395 is formed by placing within the thermocouple junction 130. Exceeding the rating of the fuse 395 across the thermocouple conductors 120 causes the device to lose the properties of a thermocouple.

Figure 4 is a drawing of an embodiment of micro-thermocouple 100 that is comprised of two thermocouple junctions 130. The first is formed by thermocouple conductors 120 and 122, and the second is formed by thermocouple conductors 122 and 424. Conductor 122 must be a different metal than conductors 120 and 424, but conductors 120 and 424 may be the same or different metals.

Figure 5 is a drawing of an embodiment of micro-thermocouple 100 that is comprised of two thermocouple junctions in a different arrangement than the junctions shown in Figure 4. In figure 5 a second thermocouple junction 530 is at a point further from the end 155 of the micro-thermocouple 100 than thermocouple junction 130. Thermocouple junction 130 is comprised of thermocouple conductors 120 and 122, and thermocouple junction 530 is comprised of thermocouple conductors 122 and 424. As in the embodiment in Figure 4, conductor 122 must be a different metal than conductors 120 and 424, but conductors 120 and 424 may be the same or different metals. Thus, thermocouple junctions 130, 530 may be the same type or may be different types. An electrically insulating seal 550 is formed over thermocouple junction 530. The arrangement of thermocouple junction 130, 530 in Figure 5 provides a measurement of temperature change at multiple locations along the length of the micro-thermocouple 100. This concept can be expanded to a thermocouple device having N thermocouple conductors, where N is an integer. If

all thermocouple conductors are used in only one thermocouple junction pair, $N/2$ thermocouple junctions are created and can be placed at $N/2$ locations along the thermocouple device to provide temperature information at the $N/2$ locations. If a thermocouple conductor is used in more than one thermocouple junction it is
5 possible to create $N-1$ thermocouple junctions from N thermocouple conductors. Again, the $N-1$ thermocouple conductors may be placed at $N-1$ locations along the thermocouple device to provide temperature information at the $N-1$ locations.

Although specific examples have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement
10 calculated to achieve the same purpose could be substituted for the specific example shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is intended that this invention be limited only by the claims and the equivalents shown.